PATENT

BULKHEAD ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a bulkhead assembly and in particular a bulkhead assembly used with an inflatable modular structure. The inflatable modular structure can be used as a spaced based platform or a habitat for use on a planet or other extraterrestrial body.

2. Description of the Prior Art

Bulkheads are used commonly in aircraft, ships, and boats as partitions to separate compartments on such craft. In this application, the bulkheads typically are walls that may or may not have doors or passageways.

Bulkheads have also been suggested for use with inflatable modular structures such as those structures identified by U.S. patent No. 6,547,189 to Raboin, et al. When used with inflatable modular structures, a bulkhead

serves a number of functions besides the traditional task of partitioning areas of a vessel.

An inflatable modular structure is a unique approach at providing a cost effective, large volume, habitable working environment for use in space and on extraterrestrial bodies. This approach is distinct due to the characteristic structure of the module.

The inflatable structure has a truss arrangement predominately surrounded by an inflatable flexible multi-layered shell. This allows for minimizing the volume of the module at launch and maximizing the volume when deployed.

In the pre-deployed configuration, the shell is folded about the truss and secured in such a way that the module can be fitted into the payload section of a conventional launch vehicle. When the payload is launched brought to a desired location, the module is transformed into a deployed configuration.

In this configuration, the flexible shell is released and the module is inflated with a gas; usually air. As the volume within the module increases, the shell unfolds and expands. When fully inflated the shell encompasses a volume that is far greater than the comparable volume in a solid hulled craft of the same launch dimensions.

The availability of a module that has a deployed internal volume that is not confined to the volume of a hard-shelled vehicle opens the way for a new paradigm impacting numerous areas in the space sciences. For example, to date the design of equipment for use on a space module has been restricted by the size of a craft's launch payload volume. Furthermore, a great deal of equipment is usually secured in a permanent location within the space

vehicle. In some cases, so secured that it cannot be removed once deployed. By virtue of an inflatable modules' larger deployed volume, the module not only reduces this restrictive parameter for equipment design, it allows for movement of the equipment from one location to another within the larger volume in a variety of ways.

Another way the prototypical approach to creating a space module is changed is in the area of cost. Presently, most modules rely upon a solid shell. The shell is a specialty item that must be intensely scrutinized as any flaws in the structure could result in a loss of air from the module and a potentially catastrophic failure; especially if a leak occurs behind a secured piece of equipment. To address this scenario a great deal of testing and inspection must be done on the hull. Further, the hull must be composed of a material that can withstand a certain level of debris impact, insure reliability, and yet be light enough for launch. These are factors that drive up the cost of a hard-shelled module.

The inflatable module utilizes reliable flexible materials with proven characteristics. Coupled with this advantage, the module has multiple layers of a flexible debris shield. The use of such a shield on a rigid hulled craft would still require the volume in the craft to be reduced to accommodate the shield. While this is a serious impediment to the internal volume of the rigid craft, it is not such a serious impact to the more voluminous flexible shelled vessel.

Even though testing and inspection is still important for a flexible module, inspection and testing of the flexible materials is typically less expensive than for a solid shelled craft. Furthermore, since the deployed

volume of the flexible craft is larger than the deployed volume of a rigid shelled craft having a comparable launch payload volume, the launch cost per cubic foot of the deployed inflatable module is expected to be far less than for the hard shelled module.

The aforementioned advantages of the inflatable module depend from the combination of an inflatable malleable shell and a rigid, or semi-rigid, truss. The truss performs the function of a skeletal backbone to the module and is integral in defining the shape of the module and insuring that the module retains a relatively constant longitudinal dimension. This is accomplished through an interaction of a variety of structural members including the longerons and braces in a truss, airlocks, and the use of bulkhead assemblies.

A bulkhead in an inflatable module should serve several functions to reduce the need for other structural elements thereby reducing cost and weight. To begin, it would be the element that receives the ends of the longerons and connects to the airlocks. Furthermore, the bulkhead would provide the support for the inflatable shell. Typical elements of an inflatable shell include a inflatable bladder, flexible restraint layer, and a meteoroid/debris shield. Each of these elements requires connection points to assist in keeping the shell in place.

The Raboin patent identifies, but does not specifically claim, the use of a bulkhead in an inflatable structure. Rather, a pass through frame is claimed. However, there is no suggestion as to how any longerons are connected to the identified bulkhead or claimed pass through frame. Furthermore, the elements securing the restraint layer and bladder are depicted in the figures as

being offset at a substantial distance from the bulkhead. This is not necessarily the optimum positioning as extending these elements away from the frame can weaken the elements as they experience forces along a moment arm. Finally, there is no mention of bulkhead load pads for distributing the forces associated with a launch.

What is needed is a bulkhead that receives one of the ends of a longeron, secures the flexible restraint layer and bladder in place without a large offset, and allows for the attachment of an airlock. Furthermore, the bulkhead, when situated within a launch payload and facing the booster, should have bulkhead load pads for the dispersing the load experienced during the launch of the module into space.

SUMMARY OF THE INVENTION

This invention is directed to a bulkhead assembly for use with an inflatable module. The inflatable module has at least two longerons, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end. The bulkhead has a plate with an inner surface, a number of longitudinal restraint fittings, a first bladder flange, a second bladder flange, a number of flange seals, and at least two longeron sleeves.

Each longeron sleeve is fixedly secured to the inner surface of the plate and each sleeve is adapted to fixedly receive a longeron. One end of the inflatable bladder is secured between the first and second bladder flanges. The second bladder flange is secured to the inner surface of the plate and the flange seals are secured between the inner surface of the plate and the second bladder flange.

The longitudinal restraint fittings are secured to the plate and each fitting receives a loop from one end of the flexible restraint layer. Thus, the bulkhead assembly provides a structure that secures the ends of the inflatable bladder, flexible restraint layer, and longerons.

As dictated by the circumstances of a particular situation, the bulkhead can have an access opening and a number of bulkhead load pads.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view of a bulkhead assembly;

Fig. 2 is an isometric view of the top of a longitudinal restraint fitting;

Fig. 3 is an isometric view of a truss with opposing distal ends;

Fig. 4 is a cross-sectional view of an inflatable module; and

Fig. 5 is a cross-sectional view of an inflatable module with longerons partial isometric view of a cover on two longerons.

DETAILED DESCRIPTION OF THE DRAWINGS

The present invention may best be understood by reference to the following description taken in conjunction with the accompanying drawings. Fig. 1 is a cross-sectional view a bulkhead assembly 100. Displayed are the elements of the bulkhead assembly 100, including the plate 102, tow of the plurality of longitudinal restraint fittings 104, the first bladder flange 106, the second bladder flange 108, the flange seals 110, and two of the longeron sleeves 112. Also present are the access opening 114 and the bulkhead load pads 116. The bulkhead load pads

116 are used for transferring force from the launch vehicle through the bulkhead plate 102 to the longerons 118 during launch. Thus, in the preferred embodiment, the load pads 116 are on the bulkhead assembly that is adjacent to the propulsion section of a launch vehicle. Also shown is an outer surface 117 for securing a structure to the plate 102 and an inner surface 119.

The longeron sleeves 112 are secured to the inner surface 119 of the plate 102 by any number of conventional means. In the preferred embodiment, this is accomplished by using a number of bolts 120 extending through a plate 122, which is part of the longeron sleeve 112, and into the bulkhead plate 102. Each sleeve receives a longeron 118. Again, the longerons 118 are fixedly secured in place by conventional means. In the preferred embodiment, a series of bolts 124 extend through the sleeve 112 and into the longeron 118. However securing means can also include welding, pressure fittings, adhesives, nuts and bolts, or a combination of any of the aforementioned means.

A bladder 124 is secured between the first bladder flange 106 and the second bladder flange 108. The bladder serves to retain the atmosphere of a deployed space module. The bladder as openings on opposing ends 125. In the preferred embodiment, a sealing material is placed on the bladder 124 around the edges of the opposing ends 125 to assist in creating a seal between the bladder flanges 106, 108 and the bladder 124. A number of flange seals 110 are positioned between the second bladder flange 108 and the plate 102. The bladder flanges 106, 018, bladder 124 and flange seals 110 are fixedly secured to the plate 102 as a unit by know means. In the preferred embodiment, the means includes utilizing a number of screws 126 extend from the

first bladder flange 106 through to the plate 102. As indicated in the figure, the bladder flanges 106, 108 abut the bladder 124 along a length of the bladder 124. In this way, the bladder is secured in place without requiring that the flanges 106, 108 extend far above the plate 102. Thus, the flanges 106, 108 are not extensively offset and do not react to torque as significantly as would a longer element.

A restraint layer 127 comprised of a number of straps 128 is used to provide support for the inflated bladder 124. The restraint layer 127 has opposing ends 129 where there are a number of loops 130. When the bladder 124 is inflated, force is transferred from the bladder 124 to the restraint layer straps 126. In this way, the straps not only restrain the dimensions of the inflated bladder, but also act to reduce the stress on the bladder.

Each strap ends in a loop 130. Each loop 130 extends about a roller 132 that is secured by a pin 134 to a longitudinal restraint fitting 104. The restraint fitting 104 is secured to the plate 102 by known means. In the preferred embodiment, a number of bolts 136 extend through the fitting 104 and into the plate 102. By having a loop 130 fit around a roller 132 that is secured to the plate 102, this is a means for securing the loop 130 to the bulkhead assembly. In the preferred embodiment, each fitting is secured to the plate, then a roller is placed within each loop, then the roller is secured in place to the fitting with the pin.

As indicated by the figure, the restraint layer 127 fits over the bladder 124. In this way, the restraint layer 127 is said to substantially encompass the bladder 124. Also, as shown in the figure, longitudinal restraint fitting 104 does not extend very far above the plate 102.

This assists in preventing torque as could be experienced by an extended moment arm from the plate. Furthermore, the fittings 104 are generally in a position adjacent to the flanges 106, 108.

The bulkhead assembly 100 provides the base for the ends of the bladder and the restraint layer as well as a structure to secure the ends of the longerons. Figure 1 shows a single bulkhead assembly. It is anticipated that a module will have such an assembly at opposing ends of a structure.

Turning now to Fig. 2, the longitudinal restraint fitting 104 is substantially "U" shaped. There are opposing posts 105 that support the pin 134 that in turn supports the roller 132. Also shown are holes 135 where botls can be inserted to secure the fitting 104 to the plate 102.

Fig. 3 shows how a bulkhead assembly 100 is disposed on the ends of a truss 138 comprised of a number of longerons 118 and support beams 140. An access opening 114 is also shown that leads into a distal end assembly 142. This assembly 142 can take the form of an airlock or storage area.

Opposite to the end 142 is another distal assembly 144. This assembly 144 can also be an airlock or storage area. Note that the end 144 is of a different shape than the distal end 142. This is to allow for a launch structure that would interface with the bulkhead load pads 116 to facilitate transferring forces experienced during launch to the longerons 118. An example of a launching structure 119 is shown attached to the pads.

Both ends 142, 144 are secured to the outer surface 117 of the bulkhead assembly. Both distal ends 142, 144

are secured to the bulkhead assembly 100 by conventional means. In the preferred embodiment, the ends 142, 144 are welded to the plate 102.

Turning now to Fig. 4, a cross-section of an inflatable modular structure 146 is shown. There are opposing distal ends 142, that can be airlocks, fixedly connected to the bulkhead assemblies 100. The longerons 118 are secured to the longeron sleeves 112 and the sleeves 112 in turn are secured to the plate 102. The bladder 124 is secured to the assembly 100 and is substantially covered by the restraint layer 127. It is important to note that while the figure displays an inflated module, the restraint layer 127 also substantially encompasses the bladder 124 when the module is not inflated. At the furthest layer, a debris shield 148 covers the restraint layer 127.

Addressing Fig. 5, two bulkheads are assembled into the module 146. There is a first bulkhead assembly 150 at the fore end of the longerons 152 and a second bulkhead assembly 154 at the aft end of the longerons 156. Both assemblies 150, 154 have access opening 114. This is the preferred embodiment. However, it is not necessary that both assemblies have an access opening. Thus, in an alternative embodiment, the first bulkhead assembly 150 would not have an access opening.

The fore ends of the longerons 152 are received in the longeron sleeves 112 of the first bulkhead assembly. The aft ends of the longerons 156 are secured in the same manner to the longeron sleeves 112 of the second bulkhead assembly 154. The fore and aft ends are secured in the same manner as described supra for attaching a longeron to a longeron sleeve as described in reference to Fig. 1. Returning to Fig. 5, the bladder is attached to the

bulkheads in the same manner as described in reference to Fig. 1, supra. Again referring to Fig. 5, the restraint layer is attached to the bulkheads as in same manner as described in reference to Fig. 1.

There has thus been described a novel bulkhead assembly for use with an inflatable modular structure. It is important to note that many configurations can be constructed from the ideas presented. The foregoing disclosure and description of the invention is illustrative and explanatory thereof and thus, nothing in the specification should be imported to limit the scope of the claims. Also, the scope of the invention is not intended to be limited to those embodiments described and includes equivalents thereto. It would be recognized by one skilled in the art the following claims would encompass a number of embodiments of the invention disclosed and claimed herein.